

Evaluation of Universal Newborn Hearing Screening with TEOAE and ABR: A Cross-Sectional Study with the Literature Review

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Abstract: Hearing Impairment (HI) is one of the most common congenital disorders in neonates which are observed as a severe and obscure handicap. The best early diagnostic methods for HI in newborns is Universal Newborn Hearing Screening (UNHS). In our country as a limited method, this method has been started since few years ago. In this study, we introduce hearing screening findings in one of the hospital in Tehran and compare with similar studies. A cross-sectional study was conducted on all newborns in Najmieh hospital between 2006 and 2007. Newborns at the first 48 h were screened using the TEOAE (Transient Evoked Otoacoustic Emission) test and the results were documented as Pass or Refer. The neonates were re-screened if they had Refer response during next 2-4 weeks. If the responses in both sessions (test and re-test) were Refer (not reactive) the infant would be referred for a final diagnosis with ABR (Auditory Brainstem Response) test before three month of age and then referred to an otolaryngologist for more evaluations. From 3818 neonates screened 90% had a pass response and 10% were referred for re-test in 2-4 months of age. Of those who were referred, only 11 (3.6%) infants had a Refer response again. Out of nine infants who were referred for ABR, only 3 subjects showed up sensory-neural hearing loss as the final diagnosis. One of them hadn't any risk factors of HI. Regarding to the results, suitable response in TEOAE test at the first time is not reliable and more screening test must be done to overrule the false negative and positive findings. One third of the children with HI hadn't any risk factor for HI and we recommend careful hearing screening for all neonates even those without any risk factor.

Key words: Hearing impairment, Universal Newborn Hearing Screening (UNHS), transient evoked otoacoustic emission (TEOAE), Auditory Brainstem Response (ABR), Iran

INTRODUCTION

Hearing loss is one of the common congenital abnormalities in infants which lead to a long-term damages and impacts. The prevalence of hearing loss alone is almost equaled with other important congenital abnormalities which its prevalence reported from, 1-60 in each one thousand infant which averagely considered as four in 1000 (Farhadi *et al.*, 2006; Thompson *et al.*, 2001).

On the other hand if in time diagnosing could change the final courses of a disease favorably (such as deafness), then that tool could have used as a kind of defense line against the disease that interpreted as screening (Helmsaz, 2003). More than 80% of the hearing loss in children are congenital and do not revealed until the child reach to the listening and speaking stage

(Jakubikova *et al.*, 2009). On the other hand in more than two-third of the cases, the parents of these children are hearing and in 50% of them there is no diagnosed risk factor which these facts reduced the parents attention to the children hearing (Farhadi *et al.*, 2006). Deafness should diagnosed before 3 months of age and the cure with hearing aids have started before 6 month of age, in order to its results in children development revealed properly (Ghirri, 2011). All these cases showed the necessity of hearing screening in infants which the best way of early detection is using universal newborn hearing screening. (UNHS) (Thompson *et al.*, 2001; Ghirri, 2011; Jakubikova *et al.*, 2009). In one of the methods of this screening, the Otoacoustic Emission (OAE) which is relatively a new technology, have used. Also, Transient Evoked OAE or TEOAE for its high accuracy, specificity and simplicity to perform, is the best method

for hearing screening which different studies reported its sensitivity rate almost 59% (from 59-100) and its specificity 95% (9-99%) (Jakubikova *et al.*, 2009; Thompson *et al.*, 2001; White and Maxon, 1995; Lutman *et al.*, 1997; De Capua *et al.*, 2007).

According to the positive false cases of OAE test, in further evaluation the ABR test (Auditory Brainstem Response) ABR have used for identifying the patients with auditory neuropathy (Farhadi *et al.*, 2006; Ghirri *et al.*, 2011). The other important point is the cost-benefit of hearing screening method which this method have not confirmed economically (Friedland *et al.*, 1996). The universal hearing screening in infants (UNHS), in comparison with clinical hearing assessment of infants with danger signal is more important (Helmsaz and Delpisheh, 2003; Nelson *et al.*, 2008). From 4-5 years ago in most of our country's hospital like other countries the hearing assessment have done by TEOAE method which its results published limitedly. In our study the hearing screening evaluated with TEOAE, method and its achievement have evaluated in comparison with recent studies.

MATERIALS AND METHODS

This cross-sectional study have conducted on all newborn infant of Najmieh hospital from first of June 2006 until the end of the December 2007. The sample size have considered by census. During 20-month study the alive newborn babies in Najmieh hospital have evaluated by OAE device model Otoread TEOAE made by Interacoustics Company in Germany (2006). In this assessment all, the parturition studied in each day have evaluated and recorded by the researchers and collaboration of nursing and supervisors office of the related wards. Then all the infants of pediatric ward evaluated after talking with one of the parents about hearing disorders and the benefits of infants universal hearing screening and satisfying them. A check list have designed with this regard and the first evaluation have done during the first 48 hour of birth and the results of OAE recorded as acceptable or pass and negative or refer. In the case of abnormality the test, have done again 2-4 week later. Before Discharging from hospital the necessary explanation have given to this child's parents which have not worrisome and the next referring have recommended for 2-4 week later. In addition to it, the second screening have done through phone call. If the results of each twice OAE were, negative or refer, after the infant preparation the ABR test have done in 3 month of age and in the case of abnormality, the patients have referred to an ear, nose and throat specialist. The results

reported in the form of simple frequency and percent. In addition to it, a review have done on the similar articles too. The present study which have evaluated the effectiveness, the accuracy of the results and diagnostic of TEOAE and ABR hearing screening in the PUBMED, IranMEDex, SID database from 2000 until now and by using the keywords of hearing screening OAE and ABR. In addition to it, similar study have evaluated separately and reported based on the studied population (with and without disability).

RESULTS AND DISCUSSION

In the first stage all the 3818 newborn infant have evaluated for hearing with TEOAE test during the study in the first or second days of life and before discharging. In the first screening stage 3426 infant (89.8) have acceptable responds (pass) and 392 infant (10.2%) have negative (refer) respond at least in one ear. 2-4 weeks later the negative respond group have evaluated with TEOAE again. Among these, 309 (78.82%) infants have referred and 83 infant have not. Among these people 298 (96.4%) infant have pass respond in the second stage and 11 (3.6%) infant have negative respond at least in one ear. From 11 infant with negative respond in second stage, nine (81.8%) infant have referred in 3 month of the age for doing ABR and two infant have not referred. Also six (66.6%) infant have normal ABR and three of them (33.3% referred in the third stage were Equivalent to 0.78. in each thousand alive birth) showed the Bilateral sensorineural hearing loss which referred to an ear, nose, throat specialist. In supplementary studies of one infant the maternal age (3 years old) and the risk of Neonatal sepsis, high consumption of gentamycin ad bilirubin (18 mg dL⁻¹) have considered as a risk factor. In the second infant, the risk factors were consanguineous and maternal age (34 years old) while the third infant have no risk factor.

The results of the similar studies with hearing screening in Iran and the world have shown in Table 1 and the results of hearing screening study on high risk and special group have presented in Table 2.

The universal hearing screening plan or NUHS have done from some years ago in Iran and a few years ago in the world and some of their results have published too. In this study which is a part of hearing screening plan of country, the evaluation have done on 3818 infant during the first two days of birth. As it seen in 10.2% of the infants the responds was negative for one ear or both in the first stage of evaluation with the TEOAE which is similar to Farhadi *et al.* (2006) in Tehran. In other similar studies of the country and world, the acceptable responds for the first stage of screening was 77-98.2 % which some

Table 1: Results of similar studies related to hearing screening in Iran and the world

References	Country	Year	Number	Sample	Time	Survey*	Results**	Explanations
Farhadi <i>et al.</i> (2006)	Tehran, Iran	2006	8490	Total births	At birth	TEOAE, Two steps ABR	1.4 per 1000 BSSNHL	Pass in 89.7% TEOAE
Jakubikova <i>et al.</i> (2009)	Slovakian	2009	109606	42-95% of total births	At birth	TEOAE, Two steps, ABR, TPM	9.4% BSSNHL	National survey
De Capua <i>et al.</i> (2007)	Italy	2007	19700	Total birthdays	3-5 days	TEOAE, Two steps, ABR	1.78 per 1000 HL	100% sensitivity TEOAE
Ghasemi	Mashhad, Iran	2006	10016	Except for high-risk infants	First day	TEOAE, Two steps, ABR	0.79 per 1000 BSSNHL	96% pass in TEOAE
Tanon-Anoh <i>et al.</i> (2010)	Côte d'Ivoire	2010	1306	87.4 % of total births	3-28 days	TEOAE, Two steps, ABR	5.96 per 1000 CHL	16.8% rejected in two stages TEOAE
Swanepoel	South Africa	2006	510	93 % of total births	0-12 month	DPOAE, Two steps, TPM	86% pass in TEOAE	Lack of full track
Eiserman <i>et al.</i> (2007)	USA	2007	4519	Randomly	Under 3 year	Four steps OAE	1.5 per 100 PHL	6% Full Track
Lin <i>et al.</i> (2005)	Taiwan	2005	3013	Total births	At birth	TEOAE, Two steps, ABR	3 per 1000 CHL	Only 1.8% referral for check
Lotfi and Morallali	Tehran, Iran	2007	7718	Total births	12-36 h	TEOAE, Three steps, ABR	1 per 1000 BCHL	92.3% pass in TEOAE
Zhang <i>et al.</i> (2008)	China	2007	1033	Total births	At birth	CEOAE, TBOAE	Improving detection with two tests	Two percentile improvement in diagnosis
Prpic <i>et al.</i> (2007)	Croatia	2007	11746	98.9 % of total births	At birth	EOAE, Two steps, ABR	6 per 1000 BPHL	94.3% pass in TEOAE
Lin <i>et al.</i> (2004)	Taiwan	2004	5938	Completely healthy children	Before discharge	OAE, Two steps, ABR	1.5 per 1000 SNHL	91% pass in OAE
Eiserman <i>et al.</i> (2007)	USA	2007	3486	Randomly	Under 3 year	Four steps OAE	1.7 per 1000 PHL	77% pass in OAE
Present study	Tehran, Iran	2011	3818	Total births days	The first two ABR	TEOAE, Two steps, BSSNHL	0.78 per 1000	90% pass in TEOAE

* OAE; Otoacoustic Emission, TEOAE; Transient Evoked Otoacoustic Emission DPOAE; Distortion Product Otoacoustic Emissions; TBOAE; Tone Burst Evoked Otoacoustic Emission; CEOAE; Click Evoked Otoacoustic Emission; ABR: Auditory Brainstem Response; TPM: Tympanometry, ** HL; Hearing Loss; BCHL: Bilateral congenital hearing loss; PHL: Permanent (profound) Hearing Loss; BPHL: Bilateral Permanent (profound) Hearing Loss SNHL; Sensory-Neural Hearing Loss; BSSNHL: Bilateral Severe Sensory-Neural Hearing Loss

Table 2: Results of hearing screening studies on high-risk and special groups

Reference	Country	Year	Number	Sample	Time	Survey*	Results**	Explanations
Ohi <i>et al.</i> (2009)	France	2009	1461	High-risk neonates	Third day	AOAE Two steps, ABR	34 /100 SNHL	4.55% hearing impairment
Baradaranfar <i>et al.</i> (2011)	Yazd, Iran	2009	35	Hyperbilirubinemia	After the diagnosis of jaundice	ABR, TEOAE	25.7% SNHL in ABR	Only 14.3% of disruption in TEOAE
Akbari <i>et al.</i> (2005)	Tehran, Iran	2005	33	Hyperbilirubinemia	After the diagnosis of jaundice	ABR, TEOAE	30% SNHL in ABR	Only 15% of disruption in TEOAE
Holster <i>et al.</i> (2009)	Netherlands	2009	340	Failing a hearing screening months	During 29 of follow-up	Further investigations special clinic	49.4% and 42.9% BSSNHL Two steps	After the rejection of TEOAE, Two steps ABR
Ahmadi <i>et al.</i> (2014)	Tehran, Iran	2010	300	Infants born by ART	At birth	Otoscopy and TEOAE, ABR	1.03% BSNHL	5.4% of disruption in investigations

*ART: Assisted Reproductive Technique; **OAE Otoacoustic Emission; TEOAE: Transient Evoked Otoacoustic Emission; ABR: Auditory Brainstem Response; ***SNHL; sensory-neural hearing loss, BSSNHL; bilateral severe sensory-neural hearing loss

of the infant of the infants group have evaluated by choosing method. Ghasemi *et al.* (2006) study which the acceptable rate in the first stage of test was 96%, the high-risk children have moved out from the study. However, with these descriptions the hearing diagnostic rate after completing the screening stage were almost equal with the presents study results (Ghasemi *et al.*, 2006). In the present study, more evaluation on the infant with pass responds have done. Therefore, according to the sensitivity rate of 60% which was in the last studies, it

have excepted that some percent of hearing loss which have not determined by TEOAE method, have detected by other method such as ABR (White and Maxon, 1995; Lutman *et al.*, 1997). A study which have done by Tamson (2001) showed that 6.5-15% of the infants with permanent hearing loss disorder have not detected by UNHS methods (Thompson *et al.*, 2001).

However, in some studies for eliminating the error possibility and false negative, the high-risk infants have evaluated separately by ABR method. In this way, the

screening sensitivity of 100% and Specificity of 99.3% have reported (De Capua *et al.*, 2007). However, in our study, the infants with acceptable responds have not evaluated and we could not comment on this issue. However, with regard to the negative respond of other studies, it could be possible to warn the parents that they should not be assure about their infant hearing health by relying on acceptable respond to TEOAE in beginning of the birth.

In our study, in the re-evaluation with TEOAE in the second stage of 2-4 weeks from 309 infant, 298 infant have pass (96.4%) respond. Therefore, the worried parents which in the first days of birth faced with refer responds of their infant should be highly assure that the reason of the negative respond could be because of the parturitions fluid and secretions in the outer ear which by passing time a high percent of negative responds changed to acceptable. The results have questioned some evaluation of the birth and if the referred system of our country improved, it have recommended that the UNHS have done in the first 2-4 weeks of birth. In addition to it, in the second evaluation the 21% reduction rate have appeared to this study which is less than some studies of developing country such as Tanon-Anoh *et al.* (2010) in Ivory Coast and Swanepoel and colleagues study in South Africa (Ghasemi *et al.*, 2006). In addition, it was higher than the developed country's study such as de capua *et al.* in Italy (De Capua *et al.*, 2007). The noticeable point is that the more evaluating session, not referring rate increased exponentially. In a way that in Eiserman *et al.* (2007) study in U.S after four-session evaluation, only 6% of the parents complete the stages (Eiserman *et al.*, 2008). Therefore, the tests and protocols which have high sensitivity in comparison with the tests that have high, Specificity seems more efficient in hearing screening of infants.

From 11 infants which in two stages of TEOAE have refer responds, nine infant referred for donning ABR and six infant have normal ABR and three infant have hearing loss. In addition, one infant have no risk factor (33.3%). Therefore, hearing assessment only in high risk infant caused the fact that at least one-third of the disease have not revealed by hearing loss. In similar studies, the same results have obtained and today's UNHS have preferred for clinical evaluation of hearing in high risk infants (Thompson *et al.*, 2001; Jakubikova *et al.*, 2009; De Capua *et al.*, 2007 and Dalzell *et al.*, 2000). Tamson in their study showed that the universal screening methods in high risk group increased the infants hearing loss from average to extreme in 10 months of the age (57% against 14%). Also, in some studies about high-risk infants group, screening with TEOAE was not enough alone and the supplementary test have required

too. On the other hand in the case of completing all three stages of screening the hearing disorder rate have reported for 50%.

The prevalence of hearing loss in this study of three case were 3733 infants. It means about 0.8 in each 1000 alive birth which is less than the worlds statistics 1-5 in each 1000 alive birth (Jakubikova *et al.*, 2009). The possible reason which could explain this difference, is that the studied population were urban and live in capital and their condition in terms of health and medical following up during pregnancy and before was better. Similar studies which have done in, developed countries and urban communities against less developed countries and rural communities have confirmed this content.

The cost of this study include TEOAE (in each session 7000 man) in each two stage by ABR cost for each patient 25000 Toman and a total evaluated for 29164000 man. On the other hand, the evaluation cost of the children with hearing disorder based on the education of exceptional children department statistics annually was >17 million toman which for three patient it was 51 million toman and the comparison of these two number revealed the cost-benefit of the screening method in infants.

However, in addition to financial cost for family and society, the psychological disorder for the person and family should have considered too. Moreover, it is not comparable with financial criterion. However, in some studies (Friedland *et al.*, 1996) the cost-benefit of this method have called into question but recent studies emphasized the cost benefit of the universal hearing screening in infants (Thompson *et al.*, 2001; Jakubikova *et al.*, 2009; Ghirri *et al.*, 2011; Nelson *et al.*, 2008 ; Lin *et al.*, 2004, 2005).

CONCLUSION

The universal hearing screening in infants although could not revealed all the hearing loss cases but in comparison with evaluation of hearing in high risk group is preferred. The UNHS cost in comparison with educational cost of deafness children which is a burden for family and society is cost-benefit. It have recommended that for increasing the identification of hearing loss children the TEOAE have done in all infants and high-risk groups. In addition to it, ABR should have done in 3 month of age. Also because of the false-positive cases which is due to the fluid build up in the ear, its better to done the infants screening in future reference of 2-4 months of the age. Moreover, the necessary education for family seems necessary to complete the three-stage screening for preventing the loss.

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REFERENCES

- Ahmadi, S.E., M.R. Nateghi, H. Gourabi, R.M. Kermani and F. Jarollahi *et al.*, 2014. Frequency of hearing defect and ear abnormalities in newborns conceived by assisted reproductive techniques in Royan Institute. *Int. J. Fertil. Steril.*, 4: 79-84.
- Akbari, M., J.M. Sadeghi and M.R. Keyhani, 2005. Locating the auditory lesions in neonates affected by hyperbilirubinemia using ABR and OAE. *Audiology*, 14: 19-25.
- Baradaranfar, M.H., S. Atighechi, M.H. Dadgarnia, R. Jafari and G. Karimi *et al.*, 2011. Hearing status in neonatal hyperbilirubinemia by auditory brain stem evoked response and transient evoked otoacoustic emission. *Acta Med. Iran.*, 49: 109-112.
- Dalzell, L., M. Orlando, M. MacDonald, A. Berg and M. Bradley *et al.*, 2000. The New York State universal newborn hearing screening demonstration project: Ages of hearing loss identification, hearing aid fitting, and enrollment in early intervention. *Ear Hearing*, 21: 118-130.
- De Capua, B., D. Costantini, C. Martufi, G. Latini, M. Gentile and C. de Felice, 2007. Universal neonatal hearing screening: The Siena (Italy) experience on 19,700 newborns. *Early Human Dev.*, 83: 601-606.
- Eiseman, W.D., L. Shisler, T. Foust, J. Buhrmann, R. Winston and K.R. White, 2007. Screening for hearing loss in early childhood programs. *Early Childhood Res. Q.*, 22: 105-117.
- Eiseman, W.D., D.M. Hartel, L. Shisler, J. Buhrmann, K.R. White and T. Foust, 2008. Using otoacoustic emissions to screen for hearing loss in early childhood care settings. *Int. J. Pediatr. Otorhinolaryngol.*, 72: 475-482.
- Farhadi, M., S. Mahmoudiyan, K. Mohammad and A. Daneshi, 2006. A pilot study of national hearing screening program. *Hakim*, 9: 65-74.
- Friedland, D.R., M.C. Fahs and P.J. Catalane, 1996. A cost-effectiveness analysis of the high risk register and auditory brainstem response. *Int. J. Pediatr. Otorhinolaryngol.*, 38: 115-130.
- Ghasemi, M.M., A. Zamanian, A. Raufsaeb, M. Farahani and S. Mahmoodian, 2006. Neonatal hearing screening with TEOAE in Mashhad city. *Iran. J. Otorhinolaryngol.*, 18: 15-21.
- Ghirri, P., A. Liunbruno, S. Lunardi, F. Forli, A. Boldrini, A. Baggiani and S. Berrettini, 2011. Universal neonatal audiological screening: Experience of the University Hospital of Pisa. *Ital. J. Pediatr.*, Vol. 37. 10.1186/1824-7288-37-16
- Helmsaz, P. and E. Delpisheh, 2003. *Handbook of Health Sciences*. 1st Edn., Mehr Publication, Amsterdam, The Netherlands, pp: 348-350.
- Holster, I.L., L.J. Hoeve, M.H. Wieringa, R.M. Willis-Lorrier and H.H. de Gier, 2009. Evaluation of hearing loss after failed neonatal hearing screening. *J. Pediatr.*, 155: 646-650.
- Jakubikova, J., Z. Kabatova, G. Pavlovcinova and M. Profant, 2009. Newborn hearing screening and strategy for early detection of hearing loss in infants. *Int. J. Pediatr. Otorhinolaryngol.*, 73: 607-612.
- Lin, C.Y., C.Y. Huang, C.Y. Lin, Y.H. Lin and J.L. Wu, 2004. Community-based newborn hearing screening program in Taiwan. *Int. J. Pediatr. Otorhinolaryngol.*, 68: 185-189.
- Lin, H.C., M.T. Shu, K.S. Lee, G.M. Ho, T.Y. Fu, S. Bruna and G. Lin, 2005. Comparison of hearing screening programs between one step with transient evoked otoacoustic emissions (TEOAE) and two steps with TEOAE and automated auditory brainstem response. *Laryngoscope*, 115: 1957-1962.
- Lotfi, Y. and G. Movallali, 2007. A universal newborn hearing screening in Iran. *Iran. Rehabilitation J.*, 5: 8-11.
- Lutman, M.E., A.C. Davis, H.M. Fortnum and S. Wood, 1997. Field sensitivity of targeted neonatal hearing screening by transient-evoked otoacoustic emissions. *Ear Hearing*, 18: 265-276.
- Nelson, H.D., C. Bougatsos and P. Nygren, 2008. Universal newborn hearing screening: Systematic review to update the 2001 US preventive services task force recommendation. *Pediatrics*, 122: e266-e276.
- Ohl, C., L. Domier, C. Czajka, J.C. Chobaut and L. Tavernier, 2009. Newborn hearing screening on infants at risk. *Int. J. Pediatr. Otorhinolaryngol.*, 73: 1691-1695.
- Prpic, I., V. Mahulja-Stamenkovic, I. Bilic and H. Haller, 2007. Hearing loss assessed by universal newborn hearing screening-the new approach. *Int. J. Pediatr. Otorhinolaryngol.*, 71: 1757-1761.

- Tanon-Anoh, M.J., D.Sanogo-Gone and K.B. Kouassi, 2010. Newborn hearing screening in a developing country: Results of a pilot study in Abidjan, Cote d'Ivoire. *Int. J. Pediatr. Otorhinolaryngol.*, 74: 188-191.
- Thompson, D.C., H. McPhillips, R.L. Davis, T.L. Lieu, C.J. Homer and M. Helfand, 2001. Universal newborn hearing screening: Summary of evidence. *J. Am. Med. Assoc.*, 286: 2000-2010.
- White, K.R. and A.B. Maxon, 1995. Universal screening for infant hearing impairment: Simple, beneficial and presently justified. *Int. J. Pediatr. Otorhinolaryngol.*, 32: 201-210.
- Zhang, V.W., B. McPherson, B.X. Shi, J.L. Tang and B.Y. Wong, 2008. Neonatal hearing screening: A combined click evoked and tone burst otoacoustic emission approach. *Int. J. Pediatr. Otorhinolaryngol.*, 72: 351-360.